IMPLEMENTATON OF A REGIONAL WAVE MEASUREMENT AND MODELING SYSTEM, SOUTH SHORE OF LONG ISLAND, NEW YORK

William G. Grosskopf[1], Nicholas C. Kraus[2], Adele Militello[3], Lynn M. Bocamazo[4]

ABSTRACT: This paper describes the wave measurement and numerical modeling components of a regional monitoring and modeling system established for the south shore of Long Island, New York. The monitoring portion was begun in April 1998 and has produced a wealth of data on waves, currents, water level, and soundings at inlets. A directional spectral wave model incorporating nested grids with fine resolution at inlets provides an efficient and accurate means of calculating nearshore waves. Validation of the modeling system is presented, together with discussion of the managerial functions of the data and model.

INTRODUCTION

The south shore of Long Island extends 184 km from Montauk Point on the east to Norton Point, which is west of Coney Island, Brooklyn. This coastal reach contains six permanent inlets, and representative average annual dredging requirements in cubic meters for the inlets, listing from east to west, are: Shinnecock – 100,000; Moriches (recently) – 100,000; Fire Island – 500,000; Jones – 100,000; East Rockaway – 200,000; and Rockaway/Jamaica Bay – 125,000. Rosati, Gravens, and Smith (1999) describe historic and recent sediment budgets for this coast, and Morang, Rahoy, and Grosskopf (1999) discuss the regional nearshore geology.

Both the U.S. Army Corps of Engineers' New York District and the State of New York have as an objective regional sediment management for the south shore, which would

1) Offshore & Coastal Technologies, Inc. – East Coast, P.O. Box 1368, Chadds Ford, PA 19317. WGrosskopf@Offshorecoastal.com.

2) U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199. Nicholas.C.Kraus@erdc.usace.army.mil.

3) Coastal Analysis, LLC, 4886 Herron Road, Eureka, CA 95503. CoastalAnalysis@home.com.

4) U.S. Army Engineer District, New York, 26 Federal Plaza, New York, NY 10278-0090. Lynn.M.Bocamazo@nan02.usace.army.mil

Report Documentation Page	Form Approved OMB No. 0704-0188

1. REPORT DATE **2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Implementation of a Regional Wave Measurement and Modeling System, South Shore of Long Island, New York**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer Research and Development Center,Coastal and Hydraulics Laboratory,3909 Halls Ferry Road,Vicksburg,MS,39180-6199**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This paper describes the wave measurement and numerical modeling components of a regional monitoring and modeling system established for the south shore of Long Island, New York. The monitoring portion was begun in April 1998 and has produced a wealth of data on waves, currents, water level, and soundings at inlets. A directional spectral wave model incorporating nested grids with fine resolution at inlets provides an efficient and accurate means of calculating nearshore waves. Validation of the modeling system is presented, together with discussion of the managerial functions of the data and model.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**10**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

integrate operations cost effectively in linking dredging, sand bypassing, breach-contingency plans, and protection of beaches vulnerable to erosion by storms. Because of the natural regional movement of sediment, the coastal influence of individual projects can far exceed their formal dimensions. As an example, recent placement of beach fill along the Village of West Hampton Dunes, located to the east (updrift) of Moriches Inlet, has increased dredging requirements for that inlet. Inlets and adjacent beaches must be connected through regional models to account for multiple and cumulative interactions along the coast. In this manner, individual projects can be managed within a single framework that accounts for wide-area benefits, as well as adverse impacts. A regional modeling system encompassing waves, currents, and longshore and cross-shore sediment transport is the backbone of the planned Long Island south shore regional sediment management system.

The New York District, State of New York, and Coastal Inlets Research Program of the U.S. Army Corps of Engineers are supporting the monitoring and modeling system, with logistical assistance from counties and communities. The monitoring program began in April 1998 with a dense array of instruments (nine separate instrument packages for waves, water level, current, and wind) placed at Shinnecock Inlet for one year to validate the circulation and wave models. Instruments are being relocated westward at yearly intervals and are presently deployed at Shinnecock Inlet, Westhampton (near Moriches Inlet), Fire Island Inlet, Jones Inlet, and Coney Island. Most instruments provide the data in near-real time (within 15 min or 2 hr, depending on instrument – see http://www.lishore.org/).

This paper describes the wave component of the comprehensive regional monitoring and modeling system. A regional modeling system for tidal circulation in the complex bay, inlet, and coastal system of Long Island was developed concurrently with the monitoring program (Militello, Kraus, and Brown 2000). The present paper, focusing on the wave measurements and modeling and the work to date, substantiates the following:

- Quantifiable estimates and/or predictions of nearshore coastal processes (for example, sediment transport) require accurate knowledge of local wave energy levels, wave directionality, tidal current, and wind.
- Reliable and properly validated boundary conditions are required, such as offshore wave directional spectra, time- and space-varying wind fields, and tide to model local wave, tide, and wind conditions. For example, wind and boundary spectra for this work were taken from a new Atlantic Coast wind and wave hindcast (Swail, Ceccacci, and Cox, 2000).
- Establishment of a method for developing appropriate boundary conditions sets the stage for future automation for forecasting, operational applications, and other engineering and environmental uses of the system.

Modeling of local wave transformation, in particular accurately describing wave transformation over an ebb shoal and channel, as well as the wave-current interaction near inlets, requires dense local bathymetric surveys and the associated gridded representations. Along the coast of Long Island, the reliability of wave and circulation modeling at inlets has been greatly improved through almost-annual bathymetric surveys at the inlets by SHOALS LIDAR (Lillycrop, Parson, and Irish 1996), supplemented by conventional surveys as necessary.

MONITORING SYSTEM

Presently, directional nearshore wave data are available at six locations within the Long Island, New York coastal area (Fig. 1). Nearshore data are being collected from gauges at Shinnecock Inlet, Westhampton Beach, Fire Island Inlet, Jones Inlet, and Coney Island. The Shinnecock, Jones and Fire Island are pressure gauge-current meter (PUV) gauges and the Westhampton and Coney Island gauges are pressure gauge arrays. Offshore wave data are available from National Data Buoy Center (NDBC) Buoy 44025, upgraded to directional capability through sponsorship of the Corps' New York District. The buoy is located about 25 nautical miles south of Fire Island Inlet. Table 1 lists the locations of the wave gauges.

All wave gauges except the Fire Island gauge, which is self-recording, report data in near-real time via the World Wide Web for display, processing, and archiving. The subsurface gauges are cabled to shore, where time-series data are transmitted to servers via telephone landlines. Data from the PUV gauges are processed by the server applying traditional spectral analysis techniques (Grosskopf, et al. 1983) and then added to the data archive. The data collected by Buoy 44025 are made available by the NDBC on the web in bulk parameter form. Because the spectra are not made available, they are synthesized for model boundary input as described below.

Supplemental data are collected to enhance understanding of the coastal processes and the accuracy of wave modeling, especially in the vicinity of tidal inlets (Fig. 1). Wind and atmospheric pressure are measured at Shinnecock and Jones Inlets. Water level and current measurements are also collected along the inlet/bay system because the nearshore wave model can incorporate circulation model results to account for the wave and current interaction at inlets (Smith, Resio, and Zundel 1999).

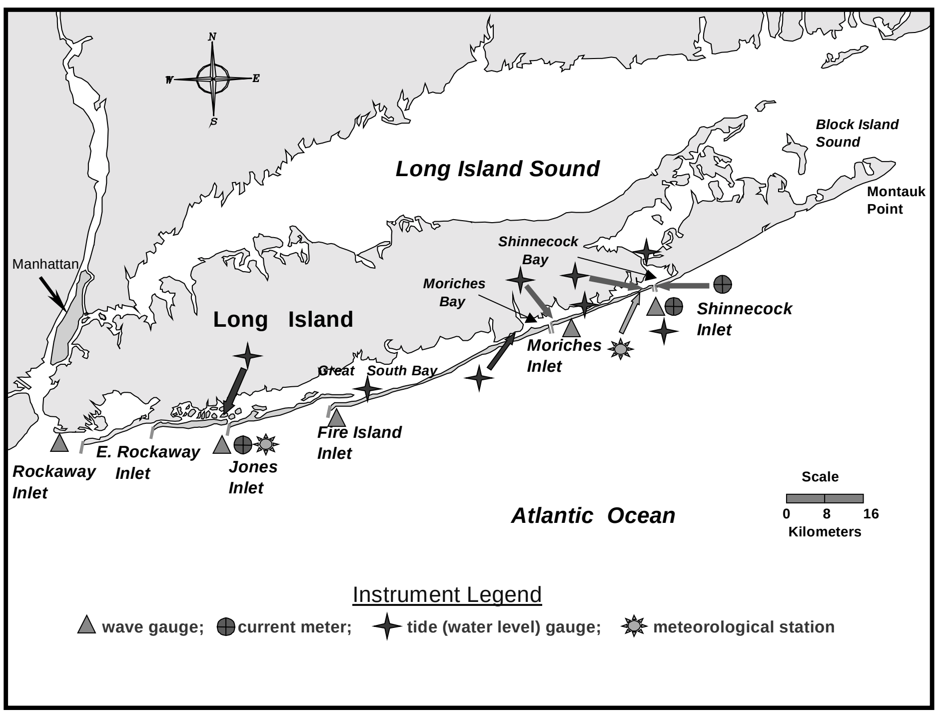

Fig. 1. Long Island overall coastal monitoring system, 1998-2002.

Table 1. Wave Measurement and Model Validation Sources			
Gauge	**Location**	**Type**	**Water Depth, m**
44025	40°15'01"N 73°10'00"W	Directional Buoy	40
Shinnecock Inlet	40°50'31"N 72°28'42"W	PUV	13
Westhampton	40°47'24"N 72°37'12"W	Pressure Gauge Array	10
Fire Island Inlet	To be determined	PUV	10
Jones Inlet	40°35'00"N 73°35'11"W	PUV	6
Coney Island	40°34'12"N 74°00'00"W	Pressure Gauge Array	6

WAVE MODELING SYSTEM

A regional calculation domain extending over the entire south shore was established for the nearshore wave directional transformation model STWAVE, which includes provision for nested grids at inlets. The model configuration allows the offshore wave boundary conditions to be specified either from numerical models (hindcast, nowcast, and forecast modes) or from offshore measurements such as at Buoy 44025. The offshore wave information and wind measurements drive a coarse-resolution STWAVE model that saves information at the offshore boundaries for local fine-resolution grids along the coast.

Simulations cover nearshore modeling for 1998 and 1999, when data were collected at Shinnecock Inlet and Westhampton. Objectives of the modeling include:

- Evaluation of the appropriateness of directional spectral boundary conditions synthesized from parametric buoy data or obtained directly from a new large-scale Atlantic Ocean wave hindcast. Because offshore hindcast wave data are often applied in coastal engineering studies and designs, the quality of new and improved hindcasting methods is of interest.
- Evaluation of the adequacy of the STWAVE directional spectral wave model in transforming offshore wave conditions to nearshore locations based upon buoy measurements and newly-hindcast offshore wave conditions.
- Assessment of model skill, such as that of STWAVE, in simulating wave transformations over a large geographic domain (herein referred to as a "regional" model) of Long Island with a reasonable grid resolution.

Bathymetry and Modeling Grids

Three wave models are operated. The first is called the Regional Long Island (Fig. 2) model having a 64 x 115 grid, oriented such that 0 deg in STWAVE corresponds to due north, with a grid spacing of 1829.27 m. Depths were developed from NOAA nautical chart data. The offshore boundary of this "regional grid" corresponds to the approximate latitude of Buoy 44025, where offshore boundary wave conditions are specified.

A second model grid was created by eliminating the southern 14 rows of the regional grid. This created an offshore boundary that coincides with the approximate latitude where newly-hindcast Atlantic Ocean waves have been made available as part of the Corps of Engineers' re-calculated Wave Information Study (WIS). The directional wave spectra are generated with AES-40 wind fields on a 5-nautical mile grid resolution.

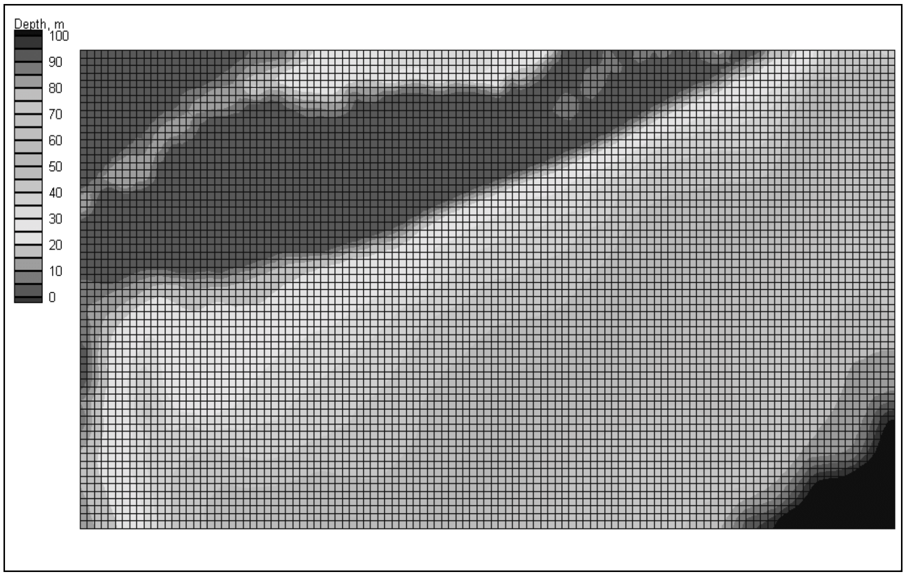

Fig. 2. Regional wave model grid (depth in m, MSL), extending from 40.1 to 41.1 deg N, 72.1 to 74 deg W at 1-nautical mile resolution.

A third model grid was prepared for the area adjacent to Shinnecock Inlet to investigate the improvement in results achieved with a finely resolved bathymetric grid in the vicinity of a local ebb shoal. Model bathymetry was collected in 1998 with the SHOALS survey system. The grid is 67 x 100 with spacing of 45.72 m. A fine grid is not required for wave model comparisons at Westhampton because the local depth contours are relatively straight and parallel. Figure 3 shows the fine-resolution grid representing Shinnecock Inlet and the location of a local nearshore wave gauge called ADVO1, denoted by a triangle.

Figure 4 summarizes the regional wave-modeling concept, with a coarse grid covering the large area of interest and finer nested grids specified at areas of complex bathymetry.

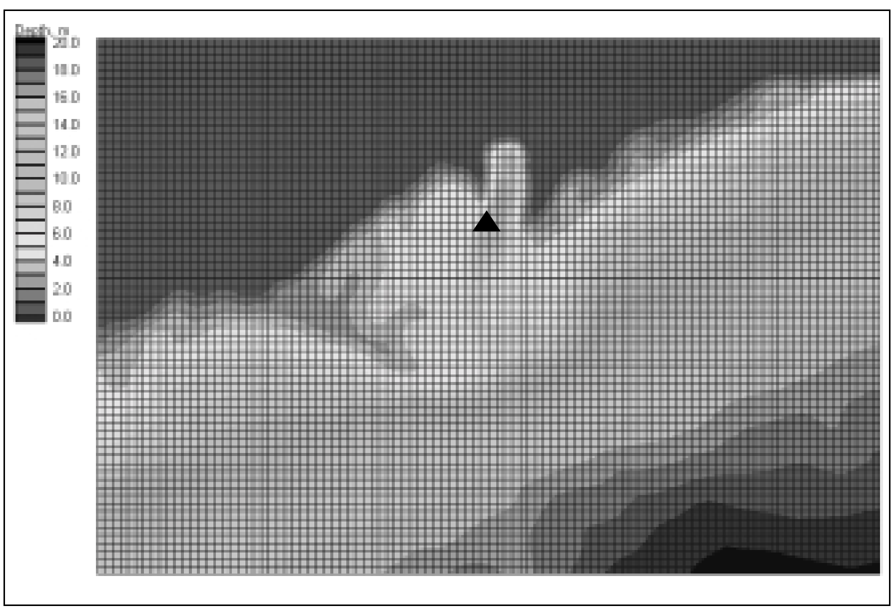

Fig. 3. Finely resolved bathymetry in Shinnecock Inlet area extending from 40.81 to 40.85 deg N and 72.45 to 72.50 deg W at 45.72-m resolution.

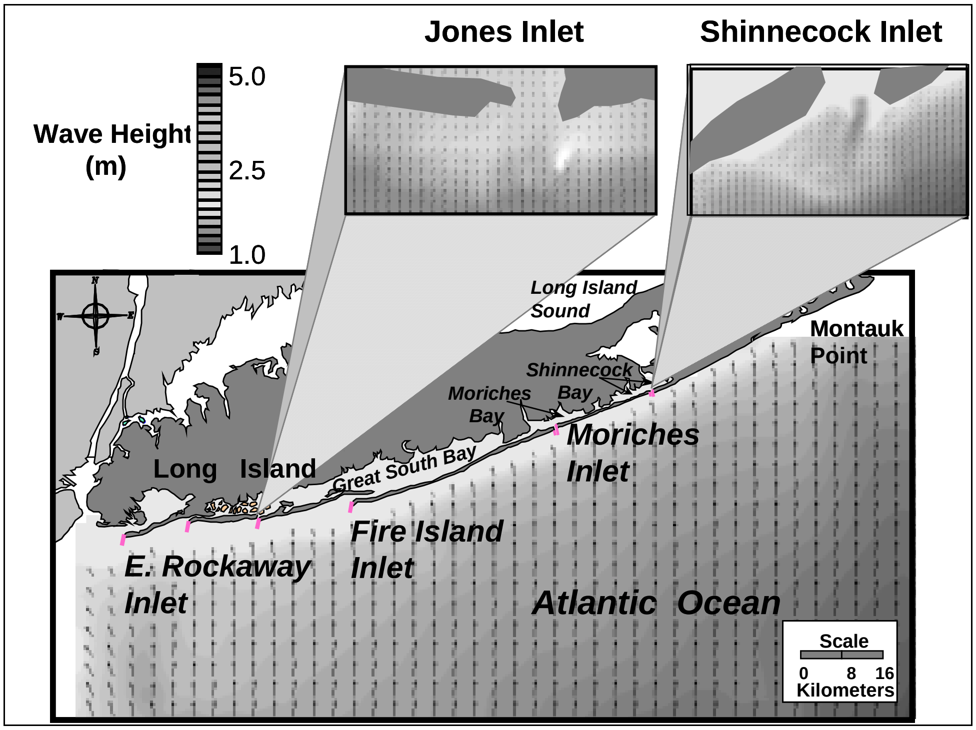

Fig. 4. Regional wave model grid with nested finer grids in areas of complex bathymetry.

STWAVE Methodology

STWAVE model runs were made with both measured Buoy 44025 bulk parameters (H_{mo}, T_p, and vector mean wave direction) and WIS-hindcast wave spectra serving as input. Because only bulk parameters were available from the buoy, spectra were synthesized with a JONSWAP shape and cosine-4th Mitsuyasu spreading. The JONSWAP peak enhancement factor was 3.3 in all cases. The two-dimensional spectra in both cases have 30 frequency bins and 35 direction bins. Because the nearshore wave transformation model STWAVE is a half-plane model, only the portion of the directionally spread spectrum that is traveling onshore (that is, with a wave angle of less than +/- 85 deg from shore-normal) is transformed through the model domain. In those cases, the input significant wave height to the model will be truncated as compared to the measured buoy wave height and the input mean wave direction will be the mean of the onshore-directed wave components.

The hindcast wave spectra were also truncated to retain only the onshore-directed portion of the directional wave spectrum. In this case only that part of the spectrum within 67.5 deg of shore-normal is retained because the directional spectra contain 20 frequency and 16 directional bins. Again, because only a portion of the spectrum is input to the model grid, the wave height, period, and mean direction can differ from values that are obtained from integrating the total hindcast spectrum.

Offshore Boundary Conditions. For the entire validation period, the hindcast wave spectra are compared to measurements at Buoy 44025. Hindcast waves from a point in 53-m water depth, located at 40.25° N, 72.5° served to develop input spectra for STWAVE as were data from the buoy located in 40-m water depth at 40.25° N, 73.17° W. Figures 5 and 6 illustrate the quality of agreement between the two sources of offshore boundary data.

The agreement in wave height is generally good; however, the hindcast model occasionally underestimates low-energy swell conditions when the directional agreement is also poor.

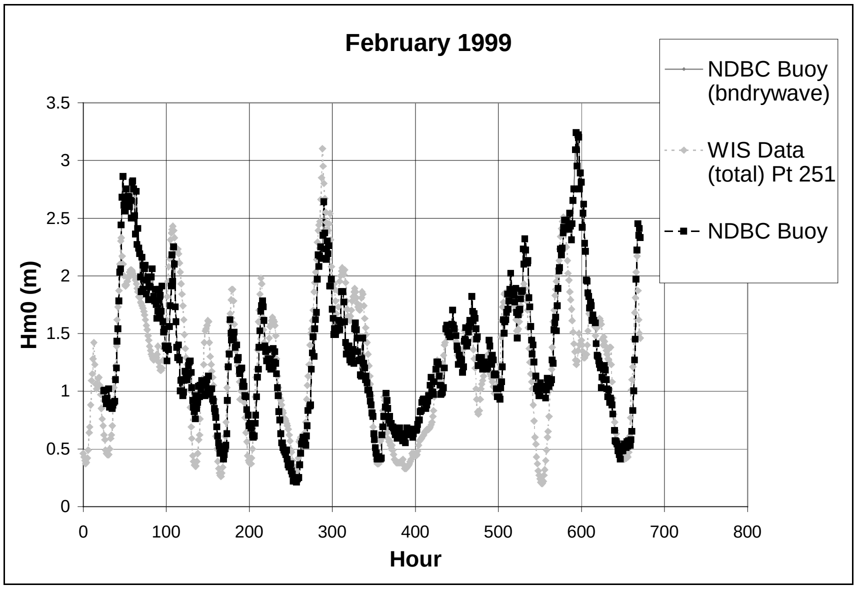

Fig. 5. Hindcast versus measured offshore wave height, February 1999.

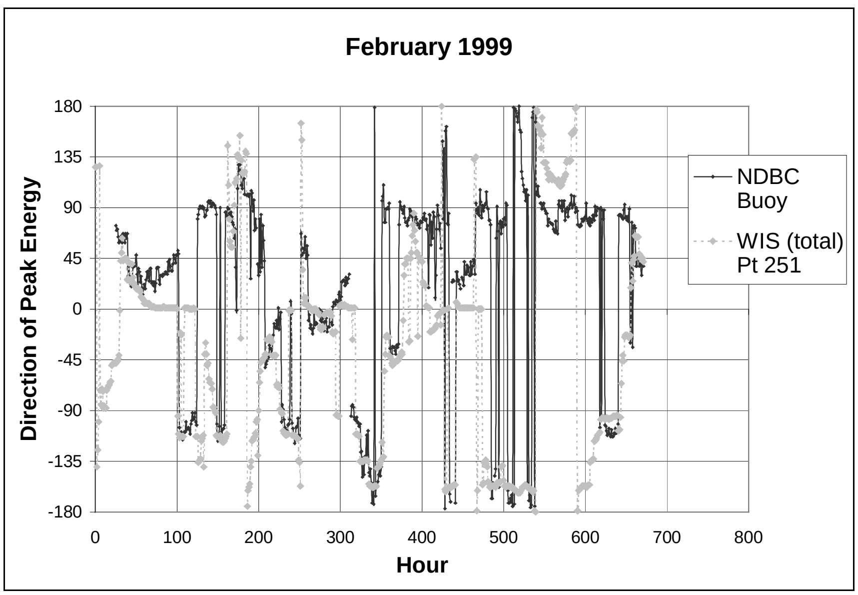

Fig. 6. Hindcast versus measured offshore peak wave direction, February 1999.

Nearshore Wave Model Validation. The directional spectral wave model STWAVE transformed the wave spectra generated from Buoy 44025 at the offshore boundary of the regional grid to the location (grid point 50, 47) of the Shinnecock Inlet wave gauge ADVO1. Hindcast wave spectra were transformed by STWAVE from the offshore boundary of the second (truncated) regional grid to the same gauge (grid point 36, 47). Figure 7 illustrates the validation and the improvement in model results if finer resolution of the bottom feature is accounted for in the wave transformation. In all simulations the

measured or hindcast wind speed and direction were included as surface wave forcing in their respective applications.

Comparison at Westhampton. To assess the need for a fine-resolution grid in an area where bottom contours are relatively straight and parallel, a comparison of the results at Westhampton are presented in Figs. 8 and 9. The plots show a reasonable validation of the regional STWAVE model (1 nautical mile grid resolution) with NDBC data as input. The greatest directional discrepancies occur when wave energy is low.

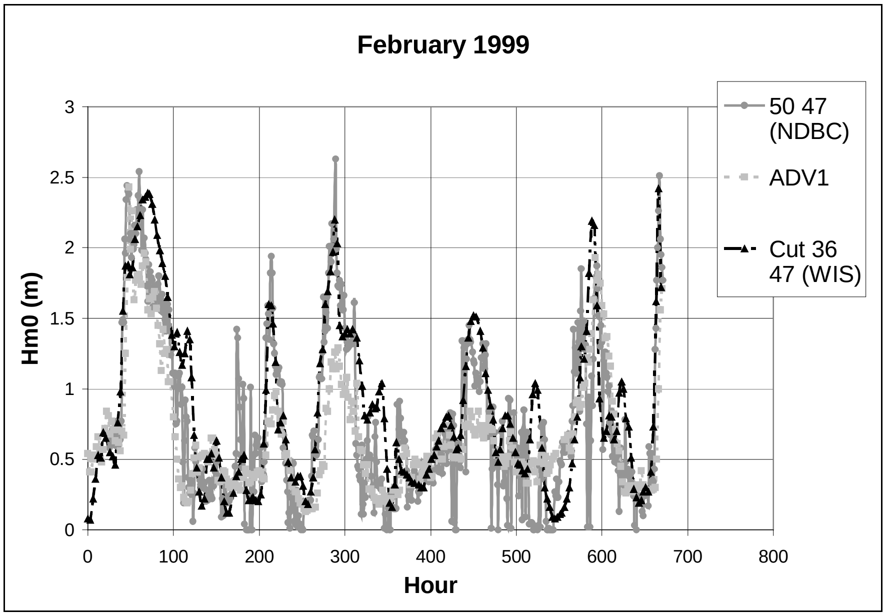

Fig. 7. Wave height comparison of transformed waves generated from Buoy 44025 and hindcast spectra versus measured nearshore waves at Shinnecock Inlet, February 1999.

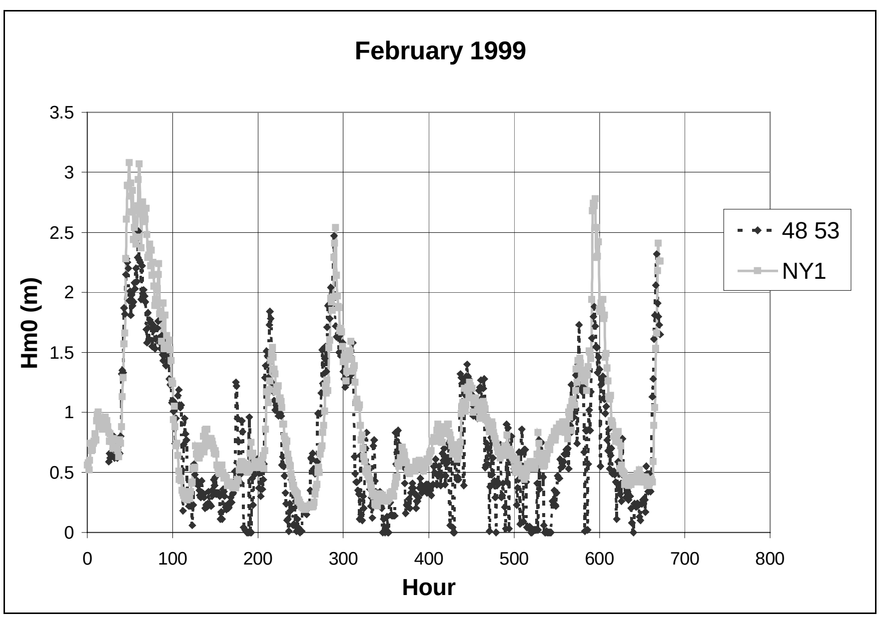

Fig. 8. Wave height comparison of transformed waves generated from Buoy 44025 versus measured nearshore waves at Westhampton, New York (NY1), February 1999.

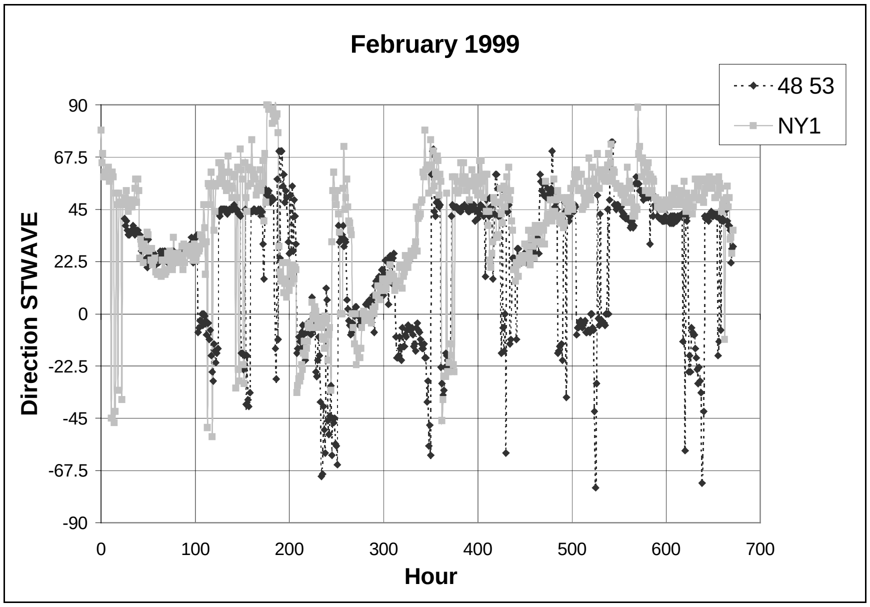

Fig 9. Wave directional comparison of transformed waves generated from Buoy 44025 and versus measured nearshore waves at Westhampton, New York (NY1), February 1999.

CONCLUSIONS AND RECOMMENDATIONS

The results presented in this paper illustrate the capability of a directional spectral wave model such as STWAVE to simulate wave transformations over a large geographic domain ("regional" model) with a reasonable grid resolution. Finer grid resolution in nearshore areas considerably improves results where bathymetric features control wave transformation. It is anticipated that further improvements would be realized if STWAVE had the capability to be driven by spatially varying wave spectra along the outer boundary, and, possibly, the lateral boundaries of the model domain. The model is now being refined to include that capability.

The applications of STWAVE demonstrate the increased utility of hindcast offshore waves that include directional spectra over synthesized spectra derived from measured bulk parameters. This directional distribution of energy obviously provides a better chance of obtaining accurate nearshore wave directions. In turn, these improved nearshore directions should provide an improved basis for estimating nearshore design conditions and sediment transport. For example, calculations made with the wave modeling results as input for the measurement period to date indicate that net sediment transport rates in Westhampton are, on average, approximately 100,000 cubic meters per year toward the west. This value compares favorably with beach profile changes along Westhampton Beach and dredging records at Moriches Inlet. To provide sufficient accuracy for such calculations, hindcasts should strive to archive directional spectra on the finest possible resolution, on the order of five degrees, which would improve the accuracy of the simulations and cause less truncation of very obliquely-traveling energy.

The nearshore monitoring system on Long Island provides a unique test bed and opportunity to monitor waves (and wind and currents) on local and regional scales for demonstrating modeling techniques on those spatial scales and the adequacy of boundary input such as the new WIS. Based upon about one year of validation, the new WIS hindcast shows considerable promise as a source of coastal information.

Ongoing expansion of the local validation process to Fire Island Inlet, Jones Inlet, and Coney Island will offer opportunity to asses the capability of simulating waves on the regional and local scales. Plans are in place to continue the effort through the measurement period and to enhance the results in areas such as tidal inlets where the tidal current, wave-induced current, and wave-current interaction are strong factors controlling the transport of sediment and morphology coastal morphology, and thus controlling the regional sediment processes.

ACKNOWLEDGEMENTS

This work was conducted as part of activities of the Inlet Modeling System Work Unit and the Inlet Geomorphology and Channels Work Unit of the Coastal Inlets Research Program, U.S. Army Corps of Engineers (USACE). Permission was granted by Headquarters, USACE, to publish this information.

REFERENCES

Swail, V.R., Ceccacci, E.A., and Cox, A.T. 2000. *Proc. 6th International. Workshop on Wave Hindcasting and Forecasting*, Meteorologial Service of Canada, Downsview, Ontario, 1-15.

Grosskopf, W.G., Aubrey, D.G., Mattie, M.G., and Mathiesen, M. 1983. Field Intercomparison of Nearshore Directional Wave Sensors. *IEEE Journal of Oceanic Engineering*, 8(4), IEEE Oceanic Engineering Society, 254-271.

Lillycrop, W.J., Parson, L.E., and Irish, J.L. 1996. Development and Operation of the SHOALS Airborne Lidar Hydrographic Survey System. In: Laser remote sensing of natural waters: from theory to practice. V.I. Feigles and Y.I. Kopilevich, ed., *SPIE-The International Society for Optical Engineering*, 2964, 26-37.

Militello, A., Kraus, N.C., and Brown, M.E. 2000. Regional Coastal and Inlet Circulation Modeling with Application to Long Island, New York. *Proc. 13th Annual National Conf. on Beach Preservation Technology*, FSBPA, Tallahassee, FL, 191-201.

Rosati, J.D., Gravens, M.B., and Smith, W.G. 1999. Regional Sediment Budget for Fire Island to Montauk Point, New York, USA. *Proc. Coastal Sediments '99*, ASCE, Reston, VA, 802-817.

Morang, A., Rahoy, D.S., and Grosskopf, W.G. 1999. Regional Geologic Characteristics Along the South Shore of Long Island, New York. *Proc. Coastal Sediments '99*, ASCE, Reston, VA, 1,568 – 1,583.

Smith, J.M., Resio, D.T., and Zundel, A.K. 1999. STWAVE: Steady-State Spectral Wave Model, Report 1: User's Manual for STWAVE Version 2.0, Instructional Report CHL-99-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.